Early Development of the Common Shiner, Notropis cornutus (Mitchill), in Southern Ontario.

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July 1986

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1455

Fisheries and Oceans Pêches et Océans

Canada

88-02635/

Canadian Technical Report of Fisheries and Aquatic Sciences

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Fisheries and Aquatic Sciences 1455

May 1986

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Minister of Supply and Services Canada 1986
Cat.No.Fs 97-6/1455 ISSN 0706-6457

Correct citation for this publication:

Leslie, J.K., J.L. Metcalfe, and K.M. Ralph. 1986. Early development of the common shiner, Notropis cornutus (Mitchill), in southern Ontario. Can. Tech. Rep. Fish. Aquat. Sci. 1455:iv+37p.

ABSTRACT

Leslie, J.K., J.L. Metcalfe, and K.M. Ralph. 1986. Early development of the common shiner, Notropis cornutus (Mitchill), in southern Ontario. Can. Tech. Rep. Fish. Aquat. Sci. 1455:iv+37p.

Early development of the common shiner, Notropis cornutus (Mitchill), obtained from southern Ontario in 1981 to 1983 and 1985, is described and illustrated. Mean diameter of preserved, fertilized eggs ranged from 1.3 mm in 1982 to 1.6 mm in 1983; hatching ranged from two days at 18.2°C to six days at 12.9°C. Newly-hatched larvae (3.0 to 4.6 mm) had a large bulbous yolk sac, incomplete mouth, pectoral fin buds, a straight urostyle, and were unpigmented. Larvae retained yolk until about 8 mm, developed all fins (at least rudimentary) by 11 mm, had 26 preanal and 13 postanal myomeres, and were characteristically pigmented with two serial rows on the dorsum, a faint lateral stripe, a ventral arrow-shaped pattern on the gut, a supra-anal spot, and an hypural patch. Prepelvic and predorsal lengths of juveniles were equal. They first developed scales at about 22 mm, and had 37 to 40 vertebrae.

RESUMÉ

Leslie, J.K., J.L. Metcalfe, and K.M. Ralph. 1986. Early development of the common shiner, Notropis cornutus (Mitchill), in southern Ontario. Can. Tech. Rep. Fish. Aquat. Sci. 1455:iv+37p.

On décrit, exemples à l'appui, l'évolution précoce du méné à nageoires rouges, Notropis cornutus Mitchill, à partir des données obtenues dans le sud de l'Ontario de 1981 à 1983 et en 1985. Les oeufs fécondés préservés avaient un diamètre moyen qui variait entre 1,3 mm en 1982 à 1,6 mm en 1983; l'éclosion se faisait dans les deux jours à 18,2° C et dans les six jours à 12,9° C. Les larves récemment écloses (3,0 à 4,6 mm) avaient un gros sac vitellin en saillie, une bouche incomplète, des boutons de nageoires pectorales, un urostyle droit, mais elles étaient dépourvues de toute pigmentation. Les larves gardaient le sac vitellin jusqu'à ce qu'elles atteignent environ 8 mm, elles avaient développé toutes leurs nageoires (au moins de façon rudimentaire) à 11 mm, elles avaient 26 myomères préanaux et 13 postanaux et elles se caractérisaient par leur pigmentation en deux rangées sur le dos, une pâle rayure latérale, un motif en forme de V sur la face ventrale, une tache supra-anale et un groupe d'hypurales. Les longeurs prépelvienne et prédorsale étaient égales chez les alevins. Les écailles apparaissaient lorsque ces derniers atteignaient 22 mm et qu'ils comptaient de 37 à 40 vertèbres.

INTRODUCTION

Notropis cornutus (Mitchill) is a well known forage and bait fish (Scott, 1967) found in the Great Lakes basin, in bordering provinces and states, as well as in eastern and central North America (Scott and Crossman, 1973). It is a mildly tolerant species, but prefers clear, running water to slow, turbid streams (Scott and Crossman, 1973). Increasing cultural eutrophication has tended to force N. cornutus to contract its range and to retreat, mainly to the north (Trautman, 1981). It may thus be considered an environmental early warning organism.

Many aspects of the life history of the adult form in the United States have been studied (Gilbert, 1964; Fee, 1965; Scott and Crossman, 1973; Trautman, 1981), but much less is known of early development. In Canada, published accounts of the biology of N. cornutus are few, and none exist of the early life history. The main purpose of this report is to provide more data (Loos and Fuiman, 1978; Perry and Menzel, 1979; Heufelder and Fuiman, 1982) on the larvae and juveniles of this species, enabling field workers to separate the young of N. cornutus from other cyprinids. For purposes of comparison, several sympatric species are briefly described.

METHODS

Specimens were obtained during field and laboratory studies in 1981 to 1983, inclusive, and 1985. In mid-June to early July, 1981 to 1983, gravid adults were collected by electroshocking in Canagagigue Creek, Ontario (43° 35'N, 80° 30'W). Eggs from 10 to 28 fish were stripped and fertilized en masse on site, using the dry method, i.e., sperm from four to eight fish was added directly to eggs, exclusive of water. Habitat water (16.5° to 18.0°C) was then used to rinse and harden eggs, which were then divided into lots and placed in rearing chambers (180 x 160 x 70 mm). In 1981 and 1982, habitat water on site was pumped at 1.1 min^{-1} through a coldwater filter. Mean incubation and rearing temperatures were 19° to 20°C. In 1983, however, two groups of fertilized eggs were transported for one hour to the laboratory, where they were incubated at two separate temperatures (14.0° and 19.5°C). On June 4, 1985, adults were seined from Canagagigue Creek and their eggs fertilized on site. The eggs were taken in thermos bottles to the laboratory, where incubation and rearing at a mean temperature of 19° to 20°C occurred in glass aquaria. In all cases, unnatural lighting and photoperiod were used. Substrate colour was black.

Eggs and larvae were removed at intervals of one or two days, and fixed and preserved with 10 percent buffered formalin and Davidson's B solution. Larvae and juveniles were seined from Canagagigue Creek on July 30 and December 12, 1985 (at 3°C), fixed with 10 percent unbuffered formalin, and the next day preserved with Davidson's B. A complete

developmental series of young N. cornutus from a single habitat thus became available. Comparative measurements were taken of young cyprinid species caught with N. cornutus in Canagagigue Creek.

Morphology is described with the aid of body measurements, which were usually of the left side of each fish. No corrections were made for length changes due to effects of fixation and preservation since they are usually inconsequential (Leslie and Moore, 1986). Linear measurements, to 0.01 mm of body parts less than 5 mm (otherwise to 0.1 mm) were taken using a dissecting microscope equipped with a calibrated ocular eyepiece, and polarized light. Diameter (random axis) of fertilized, preserved eggs was measured using a compound microscope. Measurements of eggs and larvae were taken two years after fixation, and of juveniles two to five months post-fixation.

Measurements were:

Total length (TL):	anterior-most point of head to tip of caudal fin.
Standard length:	anterior-most point of head to posterior extremity of notochord or hypurals.
Fork length:	distance from anterior margin of head to centre of caudal fin.
Preanal:	anterior extremity of head to centre of anus.
Snout:	anterior-most point of upper jaw to anterior rim of orbit.
Orbit:	horizontal diameter of orbital rim.

Head:	anterior-most point of head to anterior margin of auditory placodes, base of pectoral fin, or cleithrum, as each develops in succession.
Snout to fin:	anterior margin of head to origin of specific fin.
Prebladder:	distance between respective anterior extremities of head and swim bladder.
Depth at anus:	depth of body exclusive of fin folds, at posterior margin of anus.
Depth at caudal peduncle:	least depth of body, excluding finfolds.
Yolk sac length, depth:	maximum horizontal length, maximum depth, respectively.
Orbit to swim bladder:	posterior margin of orbit to anterior-most margin of swim bladder, as observed with transmitted light.
Swim bladder to anus:	posterior margin of swim bladder to centre of anus, as observed with transmitted light.

Myomere counts were made according to Siefert (1969), except that the final postanal incomplete segment was included in the total count. Vertebrae counts included Weberian and urostylar components. Internal morphology and meristics were determined with the clearing and staining method of Dingerkus and Uhler (1977). A camera lucida and a microprojector were used to assist in illustrations, which were of actual specimens (without generalization).

A temperature unit (T.U.) is the product of the mean daily temperature (°C) and number of hours post-fertilization divided by 24.

DESCRIPTIONS

1. Eggs and Embryos

Preserved, fertilized eggs: generally light to golden yellow, almost spherical, oil globules absent, perivitelline space one-quarter total volume, chorion unsculptured; diameter 1.5 mm (N = 121) in 1981, 1.3 mm (N = 212) in 1982, and 1.6 mm (N = 124) in 1983.

Hatching in 1981: 2 days at 18.7° ± 3.9° to 20.8° ± 2.6°C (37.4 to 41.6 T.U.). In 1982, 2 days at 18.2°C (35.7 T.U.), or 3 days at 17.5°C (52.4 T.U.). Hatching in 1983: 6 days at 12.9° ± 0.2°C (78.4 T.U.) and 3 days at 20.7°C (62.1 T.U.). Laboratory-reared specimens did not utilize cement glands, if any. Mode of hatching not observed; all newly-hatched larvae were lying on their side on the bottom of the aquarium.

Embryos: gastrula germ ring present at 10.5 hours (5.7 T.U.); blastoderm forms 80 percent of egg mass; perivitelline space 45 percent capsule diameter. At 14.0 T.U., gastrula stage, germ ring forms blastopore; yolk plug evident.

Early cleavage: egg diameter 1.7 mm; 2 hours (35.7 T.U.) post-fertilization, vitelline membrane separated from yolk; perivitelline space about 20 percent of capsule; blastodisc on verge

of division into 16 cells (Fig. 1a); blastomeres elongate, irregular, protuberant, opaque, white; micropyle visible; egg unpigmented. Tail-bud stage (Fig. 1b) at 13.0°C (41.9 T.U.) optic lobes prominent, notochord visible; auditory ossicles minute, yolk deeply invaginated near gut; body engulfs most of yolk; embryo milk-white.

Tail-free stage (Fig. 1c); 52.7 T.U.: egg 1.7 mm; tail bud broad, free, curled to right side of main axis of body; head flat, optic lobes flat, cups forming; yolk massive, anteriorly bi-lobed, micropyle present.

Late embryo (Fig. 1d) reared at 12.8°C (78.2 T.U.) and 18.9°C (45.1 T.U.): egg 1.7 mm; embryo about 4.0 mm; major ventricles of brain, eyes prominent; optic cups, lens visible; yolk much reduced in size, somites, anus visible; head, body unpigmented.

2. Yolk Sac Larvae (hatch to 7.9 mm)

(a) Morphology

Hatch (3.0 to 4.6 mm): head deflected centrally over anterior margin of bulbous yolk sac (Fig. 2a), eye oblong, or "bean-shaped"; mouth incomplete; adhesive glands not evident; eyes with choroid fissure; yolk light yellow, finely granular, anterior margin of yolk sac clear; median fin fold commencing dorsally at ninth or tenth myomere, continuous with ventral fin fold, which terminates near posterior third of yolk sac; fin fold at caudal area spatulate; anus

abruptly decurved (90°), extended to margin of ventral fin fold, pectoral fin buds present, barely discernible; notochord straight, except at posterior extremity, which may be slightly flexed, decurved, or wavy.

Length 4.3 to 6.9 mm: cleft between head and yolk sac obvious (4.5 mm), head free from yolk sac (5.0 to 5.5 mm) (Fig. 2b); cleithrum visible (5.9 mm); caudal peduncle definable (6.3 mm) (Fig. 2c); urostyle may appear flexed at 5.0 mm, true flexure at 6.8 to 7.0 mm; initial rays in ventral of caudal fin fold (6.7 to 6.9 mm); origin of ventral fin fold at fourth myomere; swim bladder evident, predorsal and preventral lengths usually equal (6.4 to 6.8 mm).

Length 7.0 to 8.0 mm: mouth terminal, complete, feeding commenced (7.0 mm); ventral fin fold originates below anterior margin of swim bladder, or below fifth preanal myomere; caudal fin fold emarginate (Fig. 3); dorsal fin anlages, hypurals forming, remnants of yolk as elongate strip along ventrum of intestine (8.0 mm).

(b) **Morphometry and Meristics**

Table 1 gives details of morphometric and meristic data for larvae 3.0 to 8.0 mm. Myomeres: 25 to 27 (modal 26) preanal, 12 to 14 (modal 13) postanal, 37 to 40 (modal 39) total.

Newly hatched larvae: predorsal and preventral length 46 percent and 65 percent, respectively; yolk sac length 2.6 mm, depth 1.0 mm, diameter of bulbous anterior 1.2 mm, depth 1.1 mm; pectoral fin bud length 0.2 mm. Length 5.0 to 8.0 mm TL: yolk sac length 3.1 to 3.7 mm, depth 0.7 mm at 5.0 mm TL to 0.4 mm or trace at 8.0 mm TL, yolk 2.9 to 3.2 mm; depth at anus 0.3 to 0.5 mm; pectoral fin 0.5 to 1.0 mm; swim bladder length 1.7 to 2.1 mm (6.6 to 7.2 mm TL), swim bladder to anus 2.0 mm. Incipient caudal fin rays: 0 to 9 (modally 1) at 6.5 mm; 0 to 18 (modally 5) at 7.5 to 8.0 mm.

(c) Pigmentation

Newly hatched (Fig. 2a): unpigmented. Length 5 to 6 mm TL: minute brown spots margin of orbit, faint, light-brown pigment dorsal margin of yolk sac; dorsally, series of paired dashes from nape to caudal peduncle (Fig. 2b). Ventrally, one or two dendritic spots anterior margin and posterior half of yolk sac, near anus, body otherwise unpigmented.

Length 6 mm: two or three stellate spots above orbit and nape; eye dark brown (Fig. 2c), small subsurface patch at heart; short anterolateral series over yolk sac; small series of dashes at site of swim bladder, above which originates single line of unequally-spaced (about 12 to 14) body-length dashes along myoseptum. Dorsally, double line (somewhat irregular) of stellate chromatophores (light-brown), nape to caudal peduncle. Ventrally, posterior

two-thirds yolk sac with series of small stellate chromatophores extending to anus, darker series thence to caudal peduncle.

Length 7 mm: dorsally (Fig. 3a), paired series of ca. 35 round and dendritic spots from nape to caudal peduncle, continuous with those at margin of urostyle, thence ventrally and forward to anus. Short series of five to ten small spots, from nape to above origin of swim bladder. Lateral of head with several spots from supra-orbital to cleithrum, at least one large, faint stellate chromatophore on snout; about six spots on surface of cheek. Irregular subsurface series from cleithrum to dorsal of swim bladder, where there are large, light-brown spots, lending distinct blotch; 35 to 40 serial spots and dashes along myoseptum, spots commence as stellate chromatophores, becoming dashed posteriorly, and end just prior to caudal peduncle (Fig 3b). Several dendritic chromatophores at site of developing ventral rays in caudal fins. Short series of five to ten small spots from nape to above origin of swim bladder. Ventrally, faint spots at margin of operculum. V-shaped series from heart to pectoral fin (Fig. 3c). A distinct arrow-shaped series (pointing anteriorly) below heart; single (sometimes partial) series of stellates from gut to anus. Series of chromatophores at base of fin fold from anus to caudal fin.

3. Larvae (8.0 to 17.0 mm)

(a) Morphology

Mouth terminal, small, slightly oblique, premaxillary not extended to anterior margin of orbit. Dorsal fin rays forming; yolk absorbed; hypurals formed (8.0 to 8.5 mm) (Fig. 3d); cleithra, pharyngeal arch and teeth, Weberian process ossified (8.5 mm); anterior swim bladder formed, segmentation in several caudal fin rays (9.0 mm); dorsal fin fold anterior to fin absorbed, anlages of rays evident in anal fin, full complement of caudal rays (9.5 mm). Caudal fin homocercal, fin fold posterior of dorsal fin absorbed (10.0 to 10.5 mm) (Fig. 4a). Pelvic fin bud present; full complement of dorsal fin rays (10.8 to 11.0 mm).

Length 11.0 to 12.5 mm (Fig. 4b): initial appearance of rays in pectoral fins. Dorsal and pelvic fin origin equal in vertical line. Ventral fin fold posterior of anus complete absorption generally coincident with attainment of full complement of anal fin rays (11.5 to 11.8 mm). Length 13.0 mm: segmentation in longest rays of median fins; premaxilla, maxilla, hypurals, vertebrae posterior of anus and several anterior-most vertebrae ossified, others less so; appearance of anlages in rays of pelvic fins, intestine commencing to loop.

First appearance of segmentation in pelvic rays (14.5 mm) and in pectoral rays at 15.4 mm. Maxilla terminates below nare, intestine S-shaped, with posterior loop adjacent to pelvic fins, anterior loop

at mid-gut, thence to anus (16 mm). Successive order of appearance of rays in fins: caudal, dorsal, anal, pectoral, pelvic.

(b) Morphometry and Meristics

Morphometric data for larvae 8.0 to 17.0 mm (N = 146) are given in Table 2, and meristic data in Table 3. Myomeres: 24 to 26 (modal 26) preanal, 12 to 14 (modal 13) postanal, 37 to 40 (modal 39) total.

Preanal length 64 to 61 percent TL (8.0 to 11.0 mm), 60 to 55 percent TL (12.0 to 17.0 mm). Length 8.0 to 9.0 mm: pectoral fin 0.8 to 1.0 mm; depth at anus 0.5 mm; prebladder 2.2 mm; swim bladder 1.1 mm. Length 9.7 mm: caudal rays typically 19, unsegmented. Length 10-12 mm: snout length 15 percent head length; prebladder 2.7 mm; prepelvic length 42 percent TL; depth at anus 0.9 mm. Length 12.5 to 14.5 mm: snout 19 percent head length; prebladder 3.6 mm; body depth at anus 1.4 to 1.5 mm, six procurrent caudal rays each on dorsal and ventral side of hypurals. Length 15 to 16 mm: predorsal 56 percent TL; prebladder 4.1 mm; body depth at anus 1.6 to 1.9 mm; pectoral fin length 1.9 mm.

(c) Pigmentation

Length 8.0 to 9.5 mm: occiput has diamond-shaped patch of about ten large, round chromatophores; snout has four or five large stellate chromatophores; gills outlined with subsurface spots; small

subsurface patch at lower base of pectoral fin; lateral line of stellate chromatophores commence above gut, decrease in size posteriorly, becoming continuous series of dashes postanally; dorsum of swim bladder densely covered with large, round spots; characteristic subsurface patch at ventral of hypurals; urostyle outlined with diffuse chromatophores (Fig. 3d). Dorsally, two lines of spots from nape to caudal peduncle. Ventral view: double series of large stellate chromatophores originate at heart, sweep epaxially to dorsal margin of intestine, thence to anus; several spots under jaw; V-shaped patch under throat, series of spots along margin of ventral fin fold from anus to caudal peduncle.

Length 11 to 14 mm: body-length areas above and below lateral line, anterior margin of swim bladder, thence to caudal peduncle all essentially unpigmented. Eyes black, tip of both jaws outlined with small chromatophores; small patch on snout; several small spots over gills; postopercular subsurface patch; vertical series of small spots at margin of operculum; body-length lateral band, composed initially of several large, round chromatophores, commencing at anterior of swim bladder; caudal peduncle with ventral patch (Fig. 4c); spot on posterior margin of anus. Brown spots on dorsal ridge of snout, nares; interorbital spots (about 14), distinct heart-shaped patch on occiput; dorsal body-length series of round spots, approximately one per myomere, extending from nape to caudal peduncle. Ventrally, about six spots scattered between mandibles; series of spots each side of gut, central series terminating at centre of gut. Dorsal and caudal fin rays pigmented, other fins not so.

Length 15 to 17 mm (Fig. 5): intensification and blending of pigmentation in all areas; ventral arrow-shaped series at gut less obvious, or indistinguishable. Spot at margin of anus remains, as does hypural subsurface patch (Fig 5b). On some specimens, surface patch of about ten large stellate chromatophores exist above anterior margin of swim bladder, at origin of lateral band. Dashes along margin of most rays of paired and median (except anal) fins.

4. Larvae and Juveniles (17.1 to 39.0 mm)

(a) Morphology

Snout pointed, mouth oblique, slightly upturned at corners; eyes large; nares large, extend to anterior margin of orbit; remnant of ventral fin fold between pelvic fin and anus usually absorbed at 17.5 to 18.0 mm; intestine S-shaped: looped on left side above pelvic fin, reverse looped above pectoral fin, thence to anus; initial appearance of segmentation in pelvic fin (17.4 mm); origin of dorsal fin above 13th vertebra, origin of anal fin below 22nd vertebra; all fins (but not all rays) segmented (19.5 mm); full complement of rays in pectoral fin (20.0 mm); snout protractile, prominent flap in large nares. Length 24 mm (Fig. 6c): essentially attainment of adult form.

Scales: cycloid; initial appearance along lateral line at trunk, anus to base of caudal fin (22.0 mm); squamation increased from

posterior of head to swim bladder (25 mm), nearly complete at 28 mm, save for dorsum of trunk; squamation complete in laboratory-reared specimens at 23 mm, otherwise at ca. 32 mm (38 scales in lateral line); scales on anterior of trunk greater in vertical than in horizontal dimension. Relative origin of dorsal and pelvic fins varied among specimens, i.e., in slight advance, slightly posterior, or in line.

Length 30 to 33 mm (Fig. 6): tip of pectoral fin extends to mid-trunk; lateral line decurved between cleithrum and pelvic fins; depressed pelvics reach posterior margin of anus; depressed dorsal fin extends to centre of anal fin base.

Length 35 to 39 mm: head dominated by large eye, located in upper half; snout rather blunt, with slight depression adjacent to nares; dorsum slightly humped, reaching maximum height at origin of dorsal fin; caudal fin medium-forked, tips rounded; anal fin slightly falcate.

(b) Morphometry and Meristics

Table 4 gives data for larvae and juveniles (17.1 to 39.0 mm). Myomeres 25 to 27 (modal 26 for larvae, 25 for juveniles) preanal, 12 to 14 (modal 13) postanal, 37 to 40 (modal 39 for larvae, 38 for juveniles) total. Vertebrae: 37 (12), 38 (23), 39 (10), 40 (1). Ten procurrent caudal rays on dorsal and nine on ventral side of hypurals (18.5 mm). Snout length 21 percent of head length;

prepectoral length 21 to 22 percent TL; pectoral fin length 2.5 mm at 21 mm TL, 4.5 mm at 31 mm TL; prepelvic length 39 to 42 percent TL; greatest depth 16 to 17 percent TL; depth at anus 11 to 13 percent TL; scales, lateral line 41 to 43 (30 mm TL). Epaxial musculature forms 43 percent (N = 40) of body depth at origin of dorsal fin.

(c) **Pigmentation**

Length 17 to 19 mm: premaxillary, ventral edge of lower lip spotted, preopercular subsurface patch; orbital rim outlined, except adjacent nares, with minute spots; patch (about 10 spots) at caudal peduncle, spots largest above gut, peritoneum grey-black, body-length narrow lateral band of individual spots, otherwise unpigmented epaxially; series of large spots extend along dorsal margin of intestine to anus, series of black dashes at base of anal fin. Dorsal of head with distinctive heart-shaped occipital patch (about 10 to 12 large, round spots); nape to mid-body with two distinct lines of dark spots, small spots interspersed; lines continue to caudal fin as distinct series of minute, closely-spaced spots. Ventral aspect: margin of gut and anus vaguely outlined with spots; pattern on gut, typical of early larvae, absent; two ventral series from anus to caudal fin base; anal fin unpigmented, dorsal fin has dashes on posterior edge of rays, caudal fin has dashes on all rays, pectoral fin has several dashes along dorsal edge.

Length 24 mm (Fig. 6a): large, subdermal chromatophores on intestine, and adjacent anus; dorsolateral series of round, black spots adjacent dorsal fin base, lateral stripe broader, less intense on central trunk than elsewhere; minute supra-anal spot persists.

Length 25 to 28 mm: spots on premaxillary, snout, interorbital area; suborbital, opercle unpigmented except upper margin, preopercular has vertical patch; light band at lateral line composed of individual spots, exclusive of epaxial region, body-length band essentially below lateral line, except at caudal peduncle; single minute spot persists on posterior margin of anus, longest anal rays with series of dashes, otherwise clear, dashes on edge of first three pectoral rays.

Length 31 mm (Fig. 6b): distinct heart-shaped occipital patch; 35 to 45 distinct round, black spots in irregular body-length series on each side of dorsal ridge; hypaxial musculature and venter essentially unpigmented (Fig. 6c).

Length 35 to 39 mm: pigmentation on side of snout dominated by light-brown patch; dark chromatophores at upper margin of opercular flap; lateral band narrow, becoming darker on posterior third of body, continuation onto base of caudal fin interrupted by narrow unpigmented area. Peritoneum dark-grey; fins milky, but rays flecked; dorsum of head has two internarial stripes, occiput dark-brown; mid-dorsal stripe narrow, fades near peduncle. Ventral of head has few chromatophores; base of anal fin black, ventral of body otherwise unpigmented, milk-white.

5. Summary of Early Development

Notropis cornutus young are moderately fusiform in lateral outline, have a preanal length generally slightly less than two-thirds TL, 26 preanal and 13 postanal myomeres, and predorsal and prepelvic of equal length. Table 5 lists developmental events in chronological order.

DISCUSSION

The process of separation and identification of larval fish begins initially with cursory observation of general body form, the relative position and shape of fins, preanal length, and patterns of pigment. As a rule, difficulties in separating young fish in a sample are inversely related to the number of dissimilar taxa present, since contrast in body form and pigmentation tends to facilitate identification. The larvae of many cyprinids are morphologically very similar and their separation consequently problematic. *Notropis cornutus* in Canagagigue Creek is sympatric with at least twelve cyprinid species, ten of which were found in 1980 (Carey *et al.*, 1983) and two more in 1985. Several of these are alike morphologically and hybridize (Heufelder and Fuiman, 1982). When present together as larvae, their separation usually requires comparative morphometric, meristic, and pigmentary analyses.

Striped shiner, Notropis chrysocephalus, are closely related and very similar in all respects to N. cornutus. They were not present in our collections, but occur with N. cornutus in several areas of the Great Lakes basin (Gilbert, 1964; Trautman, 1981; Dowling and Moore, 1984). Scott and Crossman (1973) cited differences in predorsal and dorsolateral scale rows and chin pigmentation of adult N. chrysocephalus and N. cornutus. Without detailed morphological and meristic measurements, however, larvae and juveniles of these two shiners may be misidentified reciprocally.

Pigmentary characteristics of newly-hatched specimens can help separate the species. N. cornutus are devoid of pigment, have several round chromatophores on the occiput, and develop a series of dashes along the myoseptum, and at about seven mm, a subdermal patch at the distal hypaxial area of the caudal peduncle. N. chrysocephalus have pigmented eyes at hatch and, at about seven mm, scattered pigment on the dorsum and lateral aspects (Yeager, 1979). The hypaxial caudal spot of a 10.0 mm larval N. cornutus is illustrated in Loos and Fuiman (1978), and of a 13.4 mm individual in Heufelder and Fuiman (1982). A minute single spot at the posterior margin of the anus is characteristic of N. cornutus, but apparently not of N. chrysocephalus (Yeager, 1979). Larvae of these species further differ according to chronological events in development, particularly completion of yolk absorption, appearance of dorsal fin rays, head length, and occipital pigmentation. Juveniles of the two species differ in length at initiation of squamation, length at absorption of fin fold, and completion of squamation (see also Heufelder and Fuiman, 1982).

Separation of Sympatric Species of Fish Larvae in Canagagigue Creek

Carey et al. (1983) caught adults of creek chub, Semotilus atromaculatus, river chub, Nocomis micropogon, hornyhead chub, Nocomis biguttatus, and N. cornutus in Canagagigue Creek. Diagnostic characteristics (Fuiman et al., 1983) of larval fish place these taxa in a group having more than 25 preanal myomeres. However, compared with N. cornutus, both S. atromaculatus and N. biguttatus have more total myomeres, and N. micropogon have comparatively greater predorsal and preanal length (Heufelder and Fuiman, 1982). N. micropogon have a slightly subterminal mouth, as do S. atromaculatus, whose pelvic fin originates in advance of the dorsal fin. N. biguttatus have a larger head and greater body depth at anus than do N. cornutus, and a dark, mid-lateral stripe and caudal spot. More detailed descriptions are provided by Kranz et al. (1979) and Perry and Menzel (1979) of S. atromaculatus, Buynak and Mohr (1980) and Cooper (1980) of N. micropogon, and Heufelder and Fuiman (1982) of N. biguttatus.

Larval spottail shiner, Notropis hudsonius, bluntnose minnow, Pimephales notatus, and blacknose dace, Rhinichthys atratulus were also present with N. cornutus in Canagagigue Creek. Early larvae of these species are similar superficially, although at about 10 mm, S. atromaculatus alone have a complete median fin fold. With development of pelvic fins, N. cornutus and N. hudsonius are separable from the remaining species on the basis of predorsal and prepelvic lengths, which in both are equal.

Specific features of the head (Fig. 7) are useful for separating the larvae. For example, N. hudsonius (Fig. 7b) have the smallest eyes (33 percent head length), and N. cornutus the largest eyes (40 percent head length). At 14 to 20 mm, the orbit of N. cornutus (Fig. 7a) remains, at about 38 percent head length, proportionally larger than sympatric species, whereas S. atromaculatus (27 to 33 percent) and R. atratulus (32 percent) have the smallest eye [data from Buynak and Mohr (1980) and Kranz et al. (1979)]. Snout length is an additional distinguishing feature, e.g., in S. atromaculatus, it is 23 percent head length, 19 percent in Pimephales notatus, and 21 percent in N. cornutus. Finally, the eye in N. cornutus and S. atromaculatus is located centrally on the head (Fig. 7a, d), and postorbital length in both is less than 50 percent, whereas in N. hudsonius, P. notatus, and S. atromaculatus, this length exceeds 50 percent (Fig. 7).

Comparative Gross Anatomical Features of Juveniles in Canagagigue Creek

Notropis cornutus (Fig. 7a) have a triangular head (Scott and Crossman, 1973); terminal mouth with premaxillary not extended to margin of orbit; premaxillaries protractile; tip of mouth above horizontal line extended through ventral margin of orbit; caudal peduncle of medium depth; caudal fin with medium fork and pointed lobes.

Notropis hudsonius (Fig. 7b) have a small, pointed head; mouth slightly inferior; premaxillaries as in N. cornutus; relative position of mouth and ventral margin of orbit as in N. cornutus; caudal peduncle shallow; caudal fin deeply forked, lobes sharp.

Semotilus atromaculatus (Fig. 7c): head large; mouth large, slightly inferior, sometimes with minute barbel; premaxillaries protractile, extend beyond anterior margin of orbit; relative position of mouth and ventral margin of orbit below extended horizontal line; caudal peduncle depth medium; caudal fin fork shallow, lobes rounded.

Rhinichthys atratulus (Fig. 7d): head dorsally flattened, pointed snout projects slightly beyond the small mouth; premaxillaries not protractile; tip of mouth, ventral margin of orbit as in S. atromaculatus; caudal peduncle deep; caudal fin fork shallow, lobes rounded.

Pimephales notatus (Fig. 7e): head small, snout blunt; mouth slightly inferior, decurved at corners; premaxillaries, relative position of mouth and orbit as in S. atromaculatus; caudal peduncle depth medium; caudal fin fork as in S. atromaculatus, lobes rounded.

ACKNOWLEDGMENTS

Jason Moore is thanked for collecting several species and C. A. Timmins and S. Bray helped with various aspects of the study. H. F. Nicholson edited the paper.

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TABLE 1: Morphometric and meristic data for Notropis cornutus (3.0 to 8.0 mm). Lengths in millimetres. N = number of larvae.

Mean TL	N	Length						Myomeres			
		Std.	Pa	H	O	Da	Pd	Pv	Pa	Po	Total (range)
3.7	27	3.7	2.9	0.6	0.3	0.2	1.7	2.4	25-27	13-14	39 (38-40)
4.3	25	4.2	3.3	0.6	0.3	0.2	1.8	2.8	25-27	13-14	39 (38-39)
4.8	49	4.7	3.5	0.6	0.3	0.3	1.9	2.8	25-27	12-14	39 (38-40)
5.3	43	5.1	3.7	0.7	0.3	0.3	2.0	2.8	25-27	13-14	39 (38-40)
5.7	25	5.5	3.8	0.8	0.4	0.3	2.1	2.8	25-26	12-14	39 (37-40)
6.3	22	6.1	4.1	0.9	0.5	0.5	2.3	2.8	25-26	12-14	39 (37-40)
6.8	46	6.5	4.3	1.2	0.5	0.5	2.4	2.7	25-26	13-14	39 (39-40)
7.3	51	6.9	4.5	1.4	0.6	0.5	2.6	2.1	26	12-14	39 (38-40)
7.8	54	7.4	4.8	1.4	0.6	0.5	2.8	2.2	25-26	12-14	39 (38-40)

Std = standard; Pa = preanal; Pd = predorsal; Pv = preventral; Po = postanal; H = head; O = orbit; Da = depth at anus

TABLE 2: Morphometric data for *Notropis cornutus* 8.0 to 17.0 mm. Lengths in millimetres. N = number of larvae; Std = standard.

Mean TL	N	Length								
		Fork	Std	Pre-				Head	Orbit	Caudal depth
				Anal	Dorsal	Ventral	Pelvic			
8.4	33		7.9	5.4	3.2	2.4		1.6	0.7	0.3
9.5	8		8.7	6.0	4.0	2.9		1.9	0.8	0.5
10.5	4		9.2	6.4	4.9	3.3	4.9	2.4	0.9	0.6
11.3	12		9.8	6.8	5.0	3.3	4.8	2.5	1.0	0.7
12.4	16		10.7	7.4	5.4	3.5	5.3	2.8	1.0	0.8
13.4	11		11.5	7.6	5.8		5.8	3.1	1.2	0.9
14.5	15	13.5	12.3	8.1	6.3		6.3	3.4	1.3	1.0
15.5	16	14.7	13.1	8.7	6.6		6.5	3.6	1.3	1.1
16.6	31	15.6	13.9	9.2	6.9		7.0	3.9	1.5	1.2

TABLE 3: Meristic data for *Notropis cornutus* (8.0 to 17.0 mm). Modal values in parentheses. N = number of specimens.

Mean TL	N	Myomeres			Fin rays				
		Preanal	Postanal	Total	Dorsal	Anal	Caudal	Pelvic	Pectoral
8.4	13	25-26	12-14	38-40 (39)			7-19		
9.5	7	26	13-14	39-40 (39)	6	4	19		
10.5	9	25-26	12-13	38-39 (39)	8	8	19	6	
11.3	8	25-26	12-13	38-39 (39)	8	6-8	19	6	
12.4	7	24-26	12-14	37-39 (39)	8	9	19	4-7	8
13.4	23	25-26	12-14	37-40 (39)	8	9	19	3-8	9-12
14.5	36	25-26	12-14	38-40 (39)	8	9	19	4-7 (6)	8-13 (10)
15.5	7	25	13	38	8	9-10 (9)	19	6-7 (6)	10
16.6	9	26	12-13	38-39 (39)	8	9	19	6-8 (8)	11-14 (13)

TABLE 4: Morphometric and meristic data for Notropis cornutus larvae and juveniles (17.1 to 39.0 mm).
Lengths in millimetres; N = number of specimens; D = dorsal, A = anal, C = caudal, Pel = pelvic, Pec = pectoral, Std = standard, O = orbit.

		Length							Fin rays				
Mean TL	N	Fork	Std	Pre-dorsal	Pre-anal	Head	O	Depth caudal	D	A	C	Pel	Pec
17.8	37	16.8	14.9	7.5	9.8	4.2	1.5	1.3	8	9	19	8	13
19.9	23	18.7	16.6	8.3	10.8	4.6	1.7	1.5	8	9-10	19	8	13-15
22.0	12	20.5	17.9	9.0	11.9	5.0	1.8	1.7	8	9	19	8	15
24.1	12	22.6	19.7	9.8	13.0	5.4	2.0	1.8	8	9	19	8	15-17
26.2	10	24.5	21.7	10.7	13.9	5.9	2.1	2.1	8	9	19	8	15-17
27.7	12	25.7	22.8	11.2	15.0	6.3	2.3	2.2	8	8-9	19	8	16-17
30.0	23	28.1	24.2	12.0	15.6	6.7	2.3	2.3	8	8-9	19	8	16-17
32.1	20	30.1	25.6	12.8	16.4	7.1	2.6	2.4	8	9	19	8	15-18
33.9	20	31.8	27.1	13.6	17.4	7.6	2.7	2.6	8	9	19	8-9	16
36.1	12	33.7	29.1	14.2	18.7	8.2	3.0	2.8	8	9	19	8	16-17
38.2	12	35.6	30.9	15.1	19.9	8.7	3.0	3.0	8	9	19	8	15-18

TABLE 5: Chronological developmental events during early life of Notropis cornutus. Lengths (TL) in millimetres.

Event	Size at Occurrence
Hatch	3.0-4.6; 5.0 (a)
Cleithrum visible	5.9
Branchiostegals formed	6.0
Predorsal and preventral length equal	6.0
Swim bladder filled	6.4-6.8; 5.3 (c)
First caudal rays	6.7-7.0; 6.7-7.6 (b); 8.2 (c)
Flexure of notochord	6.8-7.0; 6.5 (c)
Feeding commenced	7.0
First hypural formed	7.2-8.0
All yolk absorbed	8.0
All hypurals formed	8.0-8.5; 8.5 (c)
First rays in dorsal fin	8.0-8.5; 10.5 (c)
Cleithra ossified	8.5
Swim bladder divided into two chambers	9.0
Full complement of rays in caudal fin	9.5; 9.2 (c)
First rays in anal fin	9.5
Caudal fin homocercal	10.0-10.5
Full complement of rays in dorsal fin	10.8-11.0
Appearance of pelvic bud	10.8-11.0; 9.7-11.5 (b)
First rays in pectoral fin	11.0-12.5
Dorsal and pelvic fin origin equal	11.0-12.5
Full complement of rays in anal fin	11.5-11.8; 12-15 (c)
Postanal fin fold absorbed	11.5-11.8
First rays in pelvic fin	13.0
Intestine commences looping	13.0
Preanal fin fold absorbed	17.5-18.0
Full complement of rays in pectoral fin	20.0; 15.5 (c)
First scalation	22.0
Squamation completed (lab-reared)	24.0
(field-collected)	32.0

(a) Loos, et al. (1979); (b) Perry and Menzel (1979); (c) Heufelder and Fuiman (1982)

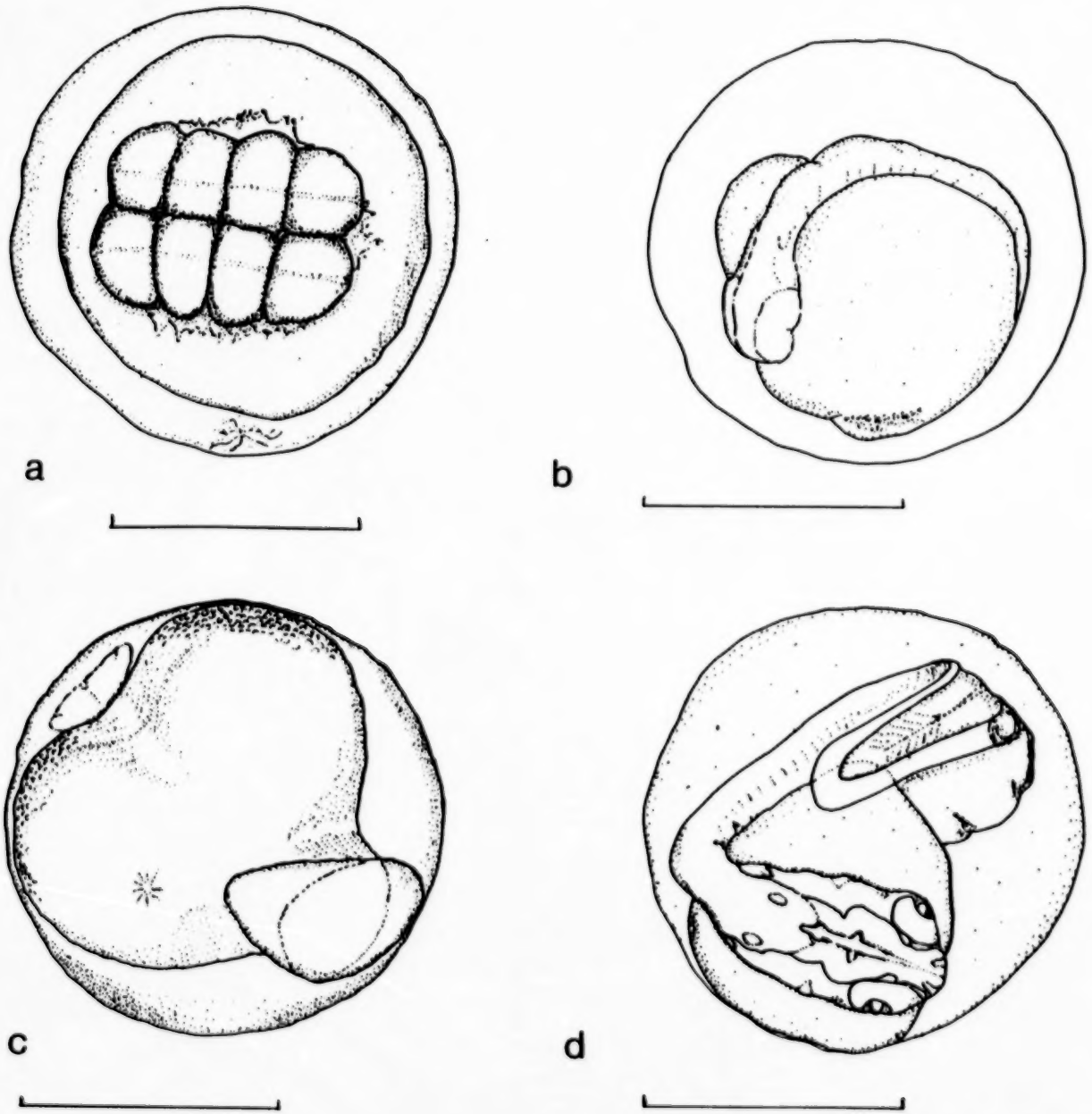

Figure 1. Notropis cornutus eggs: (a) early cleavage, (b) tail-bud, (c) tail-free, (d) late embryo. Length bars = 1 mm.

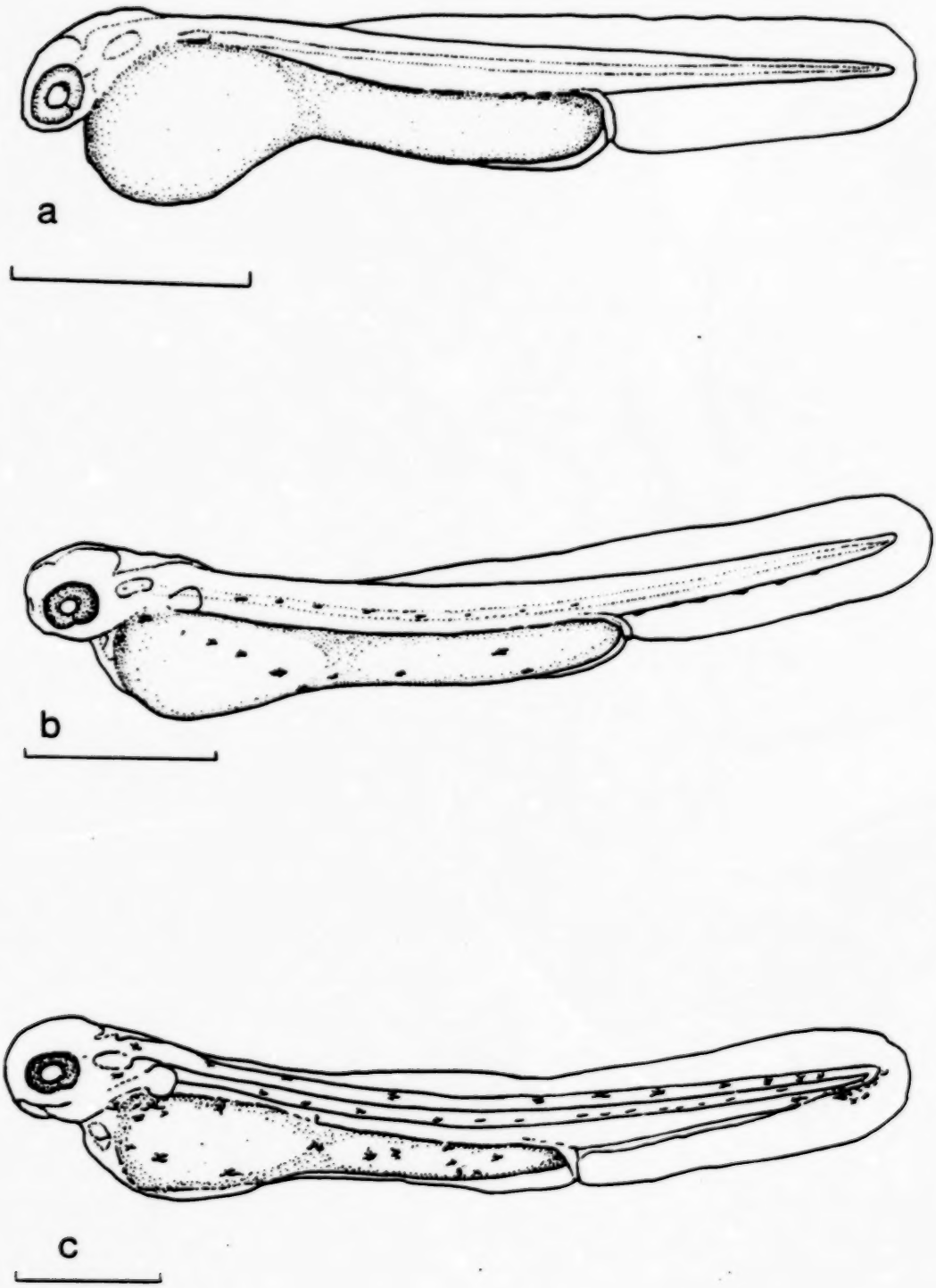

Figure 2. Notropis cornutus 3.8 mm (a); 4.8 mm (b); 6.2 mm (c) lateral view in total length. Length bars = 1 mm.

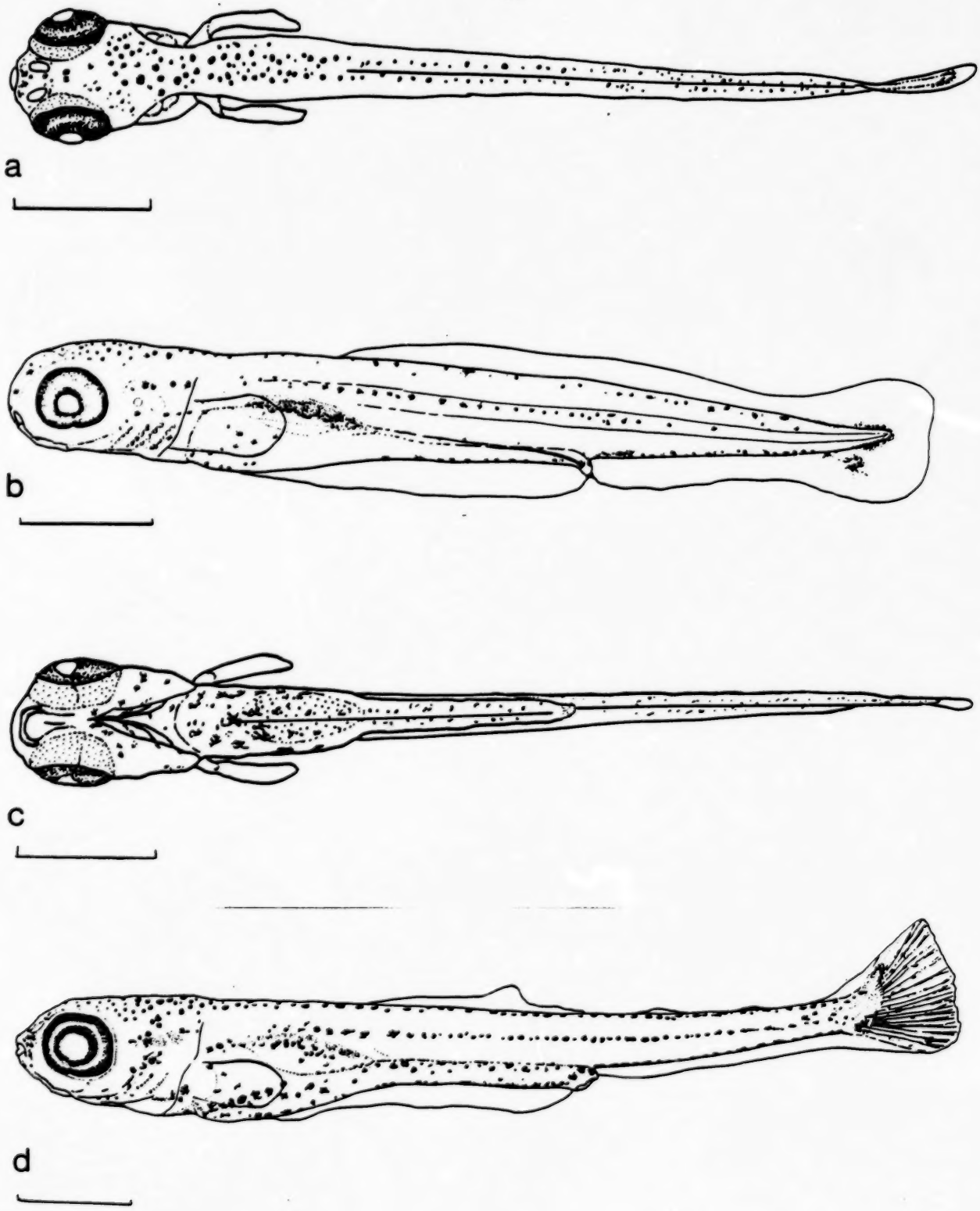

Figure 3. Notropis cornutus 7.0 mm (a - dorsal, b - lateral, c - ventral view); 8.4 mm (d - lateral view) in total length. Length bars = 1 mm.

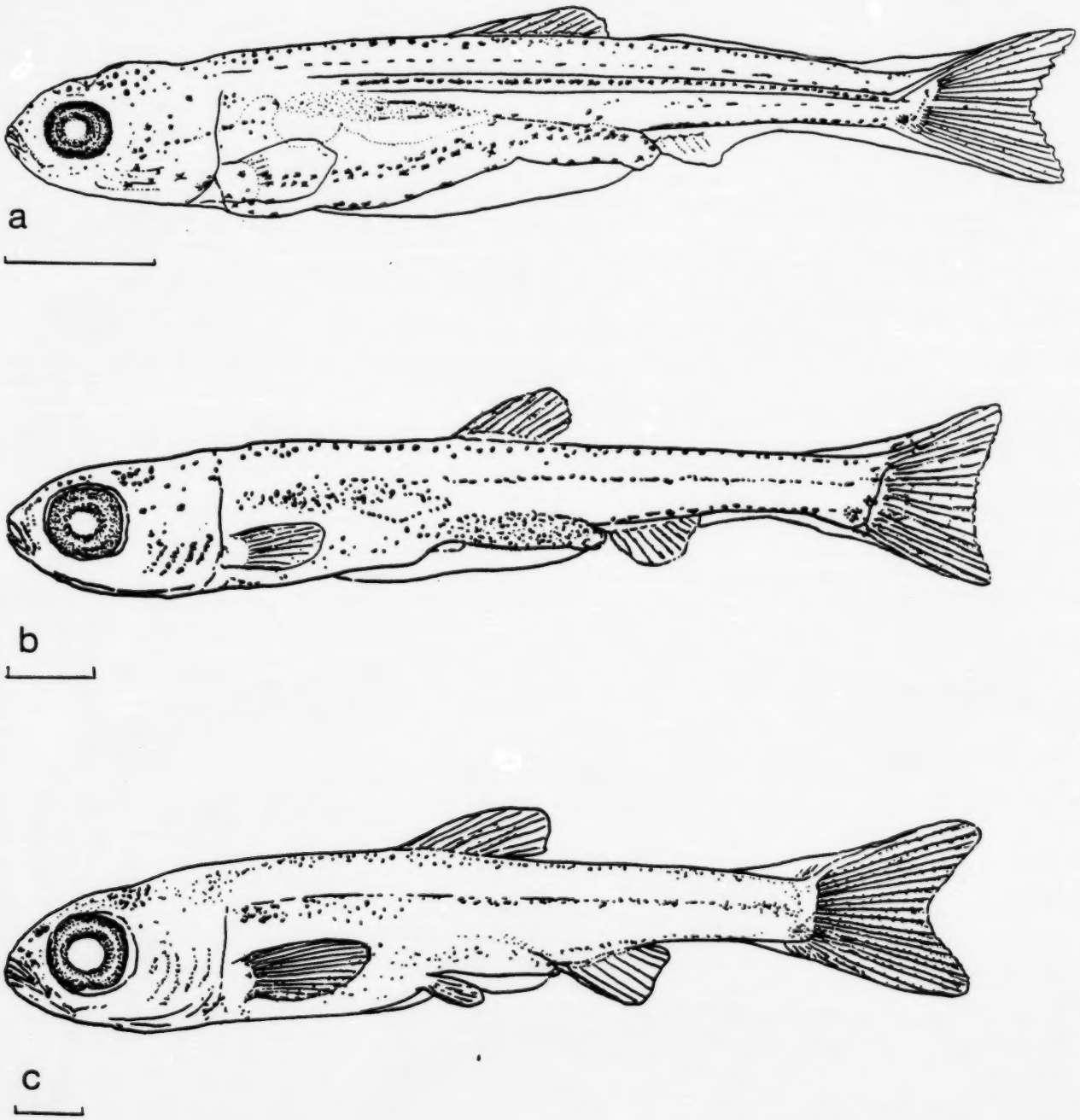

Figure 4. Notropis cornutus 10.1 mm (a); 12.1 mm (b); 13.9 mm (c) lateral view in total length. Lengths bars = 1 mm

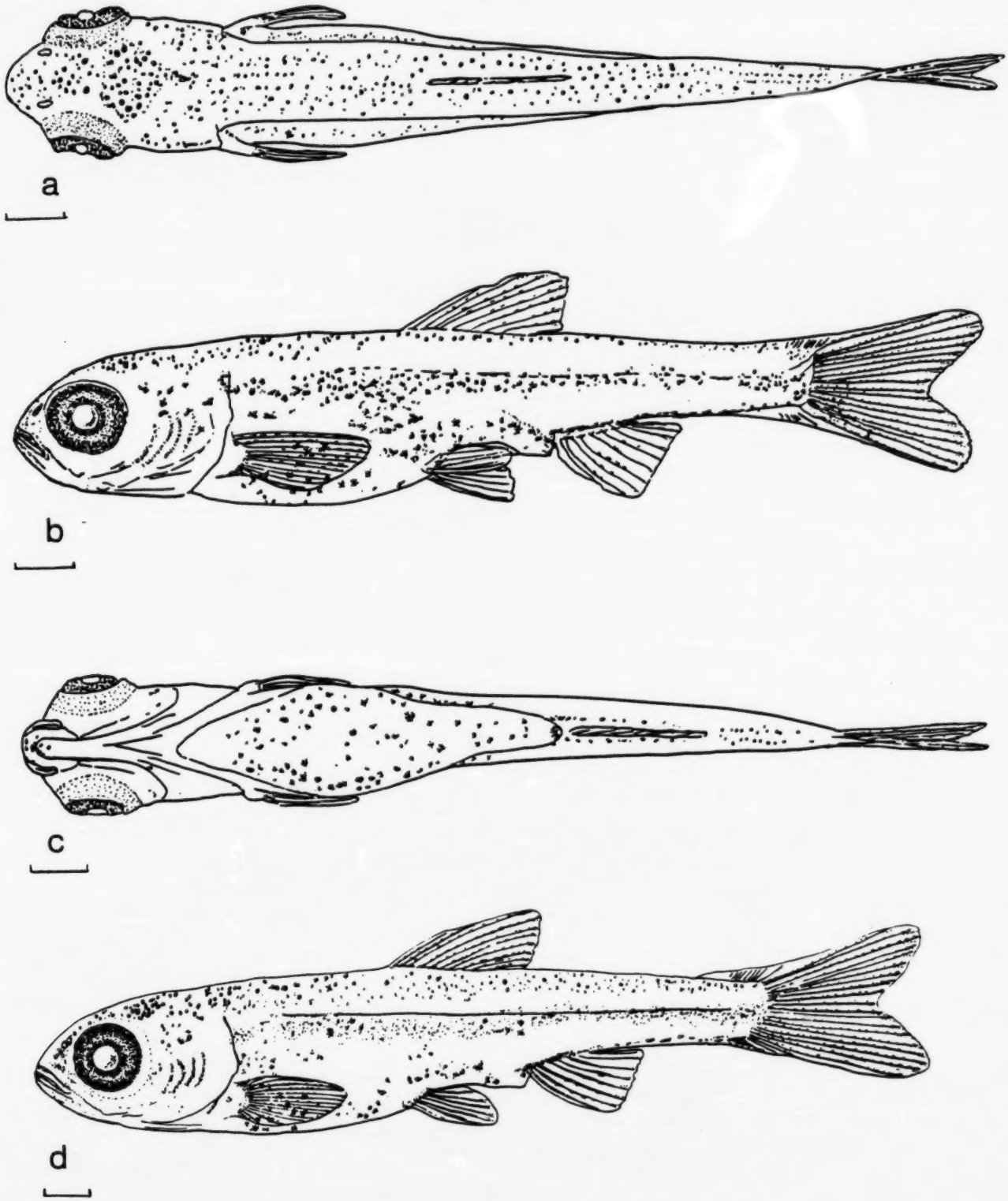

Figure 5. Notropis cornutus 16.8 mm (a - dorsal, b - lateral, c - ventral view); 20.2 mm (d-lateral view) in total length. Length bars = 1 mm.

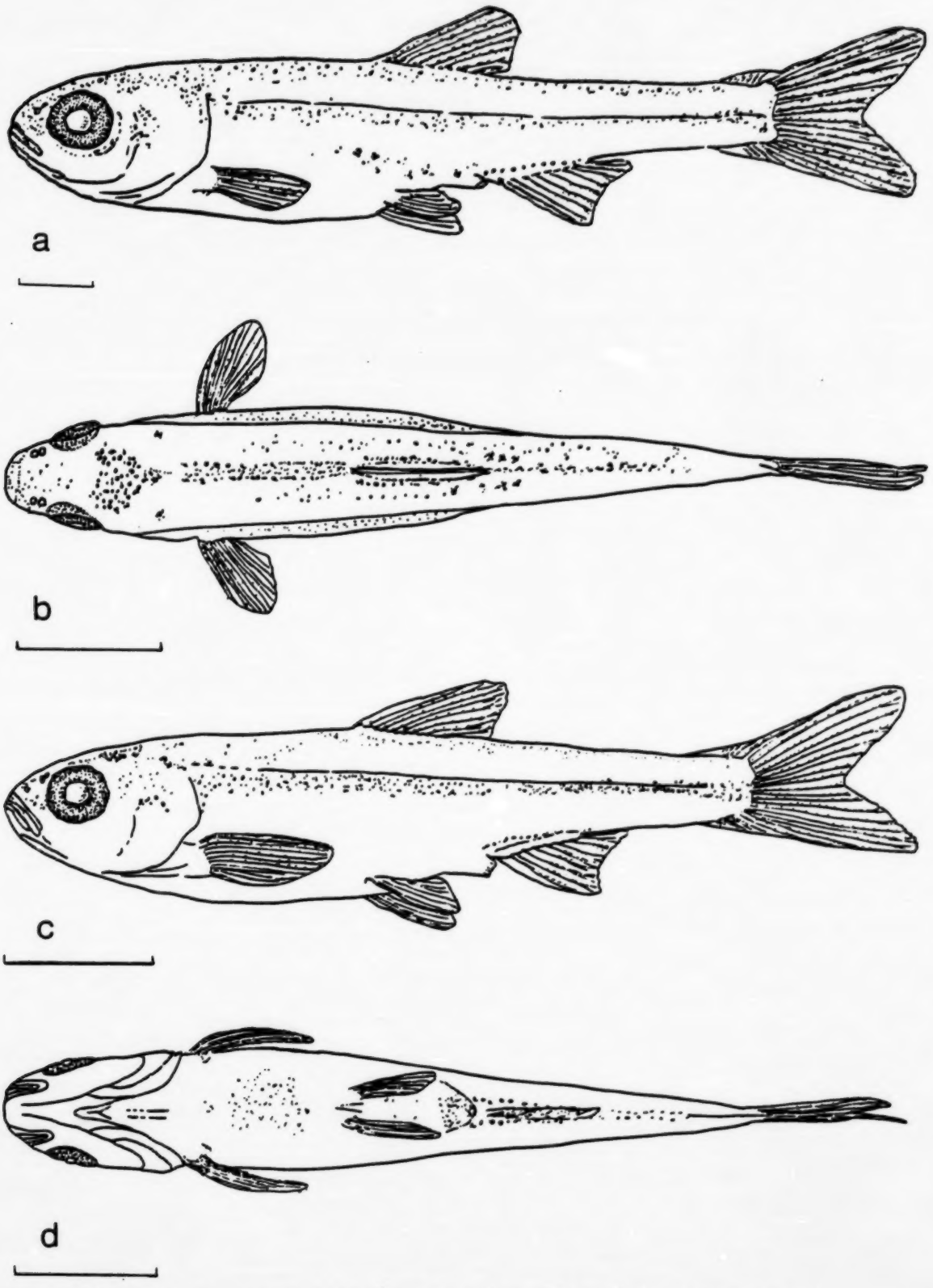

Figure 6. Notropis cornutus 24.0 mm (a - lateral); 31.0 mm (b - dorsal, c - lateral, d - ventral view) in total length. Length bars = 5 mm.

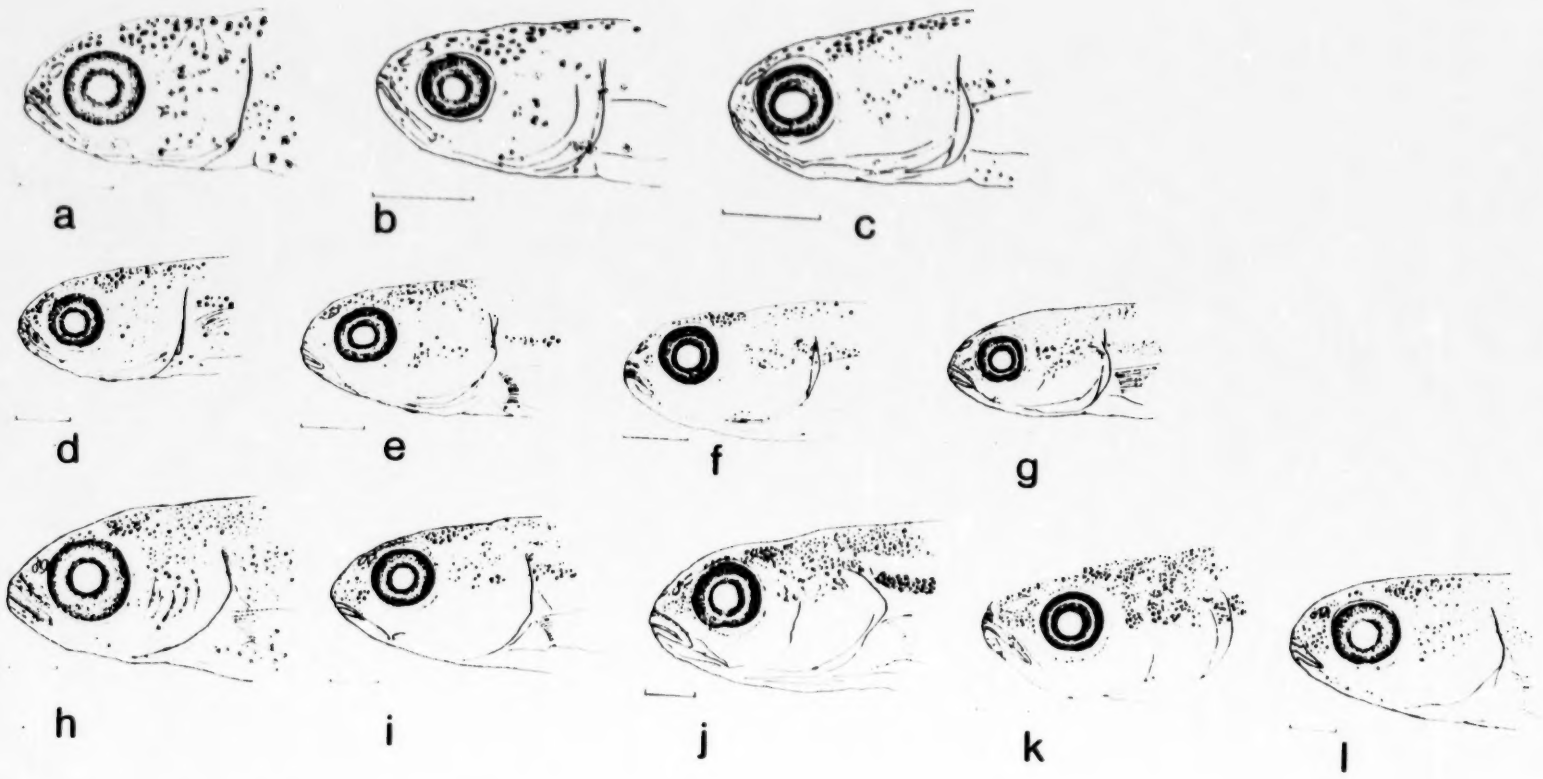

Figure 7. Head of larval cyprinids in three successive, comparable stages of total length. Top: 10 mm, (a) Notropis cornutus, (b) N. hudsonius, (c) Semotilus atromaculatus; middle: 14 mm, (d) N. cornutus, (e) N. hudsonius, (f) S. atromaculatus, (g) Rhinichthys atratulus; bottom: 20 mm, (h) N. cornutus, (i) N. hudsonius, (j) S. atromaculatus, (k) R. atratulus, (l) Pimephales notatus. Length bars = 1 mm.